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TECHNIQUES WITH H^o PRODUCED FROM POLARIZED H^- BEAMS

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I. INTRODUCTION

It is possible to perform useful manipulations by making H^o beams from polarized H^- beams with stripper foils or stripping magnets (Sec. II). The hyperfine interaction (Sec. III) modifies the behavior of the proton polarization in H^o, producing both useful and unwanted effects. Some depolarizing effects (Sec. IV) can be minimized.

II. STRIPPING

<u>Foil Stripping</u>. H^o is created by H^- stripping in a thin layer of material and in turn is depleted by stripping to H^+. In a layer of thickness t, neglecting direct $H^- \to H^+$ conversion,

$$H^o \text{ fraction} = \frac{\lambda_-}{\lambda_o - \lambda_-}\left(e^{-t/\lambda_o} - e^{-t/\lambda_-}\right)$$

where λ_- = stripping length for $H^- \to H^o$, and λ_o = stripping length for $H_o \to H^+$. Thin plastic foils are convenient to use for strippers; approximate (±10%) values for stripping lengths[1] are λ_- = 30 $\mu g/cm^2$, λ_o = 60 $\mu g/cm^2$. The maximum H^o yield is about 50%.

<u>Field Stripping</u>. Stripping of relativistic H^- beams will occur from the rest-frame electric field $E = \eta cB$ produced by a transverse magnetic field B, where η = beam momentum/H^- mass. Stripping length vs. field is plotted in Fig. 1, from the function fitted in a recent LAMPF experiment.[2]

The variable path length in the magnet, up to the point of H^- stripping, adds to the H^o beam divergence in the bend plane. The fringe field produced by a simple square-edged 16 mm magnet gap added 1.6 mr (FWHM) to the 800-MeV beam divergence in the experiment of Ref. 2.

To preserve the beam polarization, H^- beams should enter the stripper magnet with polarization parallel to the field direction. The other components of the polarization tend to be lost. A conceivable application of a stripper magnet could be as a spin filter to reduce small unwanted components.

The polarization transfer in magnetic stripping of $H^- \to H^o$ was measured to be close to 100% (no loss measured at the 1% level). Possible depolarizing mechanisms are discussed below.

III. HYPERFINE INTERACTION

Zero-field Free Oscillation. In the initial H^0 beam, half the atoms have electron spin antiparallel to the proton spin. The hyperfine interaction causes the spins to trade orientation at the hyperfine frequency $f = 1.4$ GHz.[1] Consequently, the beam polarization oscillates between its maximum P_0 and 0: $P = P_0\,(1 + \cos\omega t)/2$, $\omega = 2\pi f$ in the beam rest frame. In the laboratory, the beam has a polarization wavelength $\lambda = \eta c f$. At 800 MeV, $\lambda = 33$ cm.

Precession. If the applied magnetic field B is small with respect to the internal atomic field $B_0 = 506$ gauss, the H^0 system precesses as a unit having the magnetic moment of the electron and a spin of one. In a magnetic region of length L and transverse field B, the precession angle is $\theta = \mu_e BL/\beta c$, $\mu_e = e/2M_e c$ = Bohr magneton. Thus the rate of H^0 precession is 330 times faster than $H^\pm$ (in low fields). The free oscillation of polarization occurs independently of precession.

At intermediate fields, the observable effect is to give two-frequency precession.[3,4] This is an added complication but can be treated without loss of polarization.[1]

An H^0 polarization precessor system for accelerated H^- polarized beams can be built using small precessor magnets (50 gauss·meters) and either a foil or field stripper. After the H^0 precessor, the H^0 is stripped to H^+ at a maximum of the free oscillation. A demonstration system was reported previously.[1]

Foil Stripping. H^{0*} made in impact stripping will quench to H^0, adding an out-of-phase component to the already-freely-oscillating H^0 over several wavelengths, and producing a partially-depolarized component.

If the process $H^- \rightarrow H^0 \rightarrow H^+$ occurs within a distance << free oscillation wavelength, then loss of polarization does not occur either from free oscillation or H^{0*} production. Thus complete $H^- \rightarrow H^+$ stripping in a single foil, which is largely a two-step process, does not depolarize.

Field Stripping. In the central field region of the stripping magnet ($\sim$1.4T), the free oscillation is absent. In the exit fringe field, the atom goes from high-field to low-field conditions, passing from free-spin to coupled-spin conditions. Thus the origin of the free oscillation is smeared along the beam axis. This process, however, is coherent or quantum reversible; the polarization can be recovered in a downstream field region, as shown in Fig. 2. Furthermore, if the stripper magnet exit fringe field falls sufficiently rapidly, the depolarization can be made small. In the polarization transfer experiment, calculation showed 1.5% expected coherent depolarization. Zero depolarization was measured with about this accuracy (1%).

IV. REFERENCES

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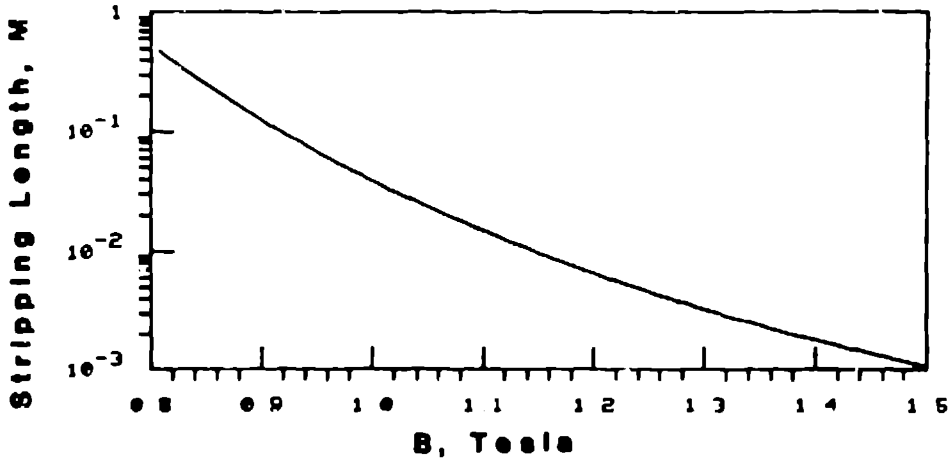

Fig. 1. H^- stripping length (1/e) vs. transverse magnetic field at 800 MeV, from Ref. 2

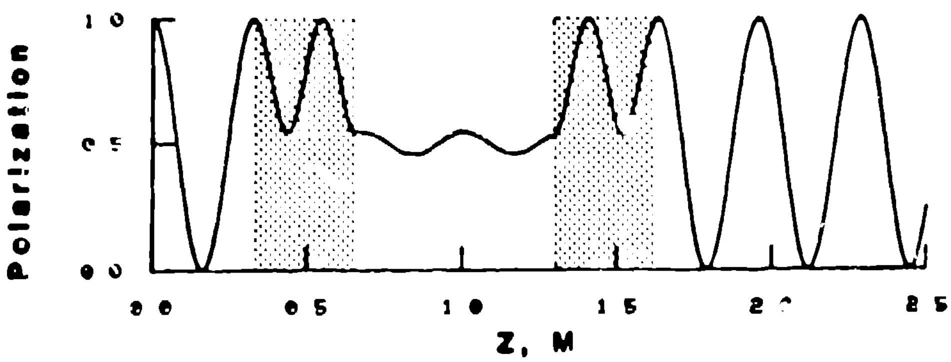

Fig. 2. H^0 polarization (upper graph) along beam axis Z, with coherent depolarization and repolarization in two 1-m, 300 gauss. magnetic field regions (shaded) parallel to polarization.

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